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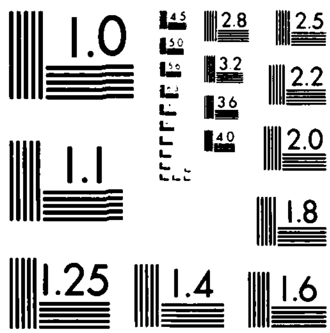

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Alternatives for Runway Rubber Removal from Porous Friction Surfaces

AD-A149 540

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16. Abstract

Review of existing rubber removal techniques was conducted. Evaluation of the effectiveness, cost, simplicity, safety, and environmental effects was ascertained when the reviewed techniques are applied solely to porous friction surfaces (PFS). Indications are that high-pressure water removal techniques should be effective on PFS. It was also indicated that chemical removal methods may be proven effective if the asphaltic binder is sufficiently chemical-resistant. However, both techniques should be evaluated on pavement test sections comprised of PFS.

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INTRODUCTION

The touchdown areas of runways serving high-speed modern aircraft are subjected to impact by the tires during landing. A certain amount of rubber is removed due to heat and abrasion as aircraft tires spin up during landing. Rubber is deposited on the pavement surface as thin layers that adhere to the pavement materials. Subsequent rubber deposits increase the buildup to significant layer thicknesses. As the touchdown area becomes covered with rubber several problems are apparent. They are 1) obliteration of pavement markings, 2) reduced wet skid resistance, and 3) accumulation of loose debris on the runway surface. Maintenance action is required to eliminate or reduce these problems to acceptable levels. Painting of pavement markings is a regular activity at all active airports; sweeping of runways is performed to remove loose debris, and rubber removal is performed to restore skid characteristics of the pavement surface.

This report is concerned specifically with the problems involved in removal of rubber deposits from porous friction course (PFC) or porous friction surface (PFS). Both terms refer to the same material, all of which will be referred to as PFS in this report.* PFS pavements are reportedly more easily damaged than dense asphalt concrete. Hence, the purpose of this report is to investigate the problem of rubber buildup on PFS and answer two questions: 1) Is it possible to remove rubber from a PFS without damage? and 2) If so, what are the best alternatives for doing so?

POROUS FRICTION SURFACES

Water deposited on runway surfaces during rainstorms may cause a serious reduction in friction between the tires of aircraft and the runway surface. This became important when high-speed jet aircraft came into general use in the 1960s. Skid resistance depends on the speed, water depth, other materials present (such as oil, fuel, rubber, etc.), and pavement surface texture. Reference 1 discusses the interdependency of texture, speed, and water depth, and their effect on skid resistance. Increased landing speeds of jets reduced the thickness of water required to produce hydroplaning and increased sensitivity to pavement texture characteristics. These factors, combined with better avionics which increased the frequency of wet weather operations, resulted in a dramatic increase in skidding accidents. One solution to this problem was the development of PFS, the first being placed on a British runway in 1962.

PFS differs from conventional dense-graded asphalt concrete in several ways. It is open graded and designed to have a total air void content of about 30 percent, rather than the 3 to 5 percent of dense-graded mixtures. The large void space allows surface water to move vertically into the void space, and then drain off the pavement horizontally. Clearly the slope from crown to edge is an important component of the overall system. Structural

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1. Lenke, Lary R., McKeen, R. Gordon, and Graul, Richard A., <u>Runway Rubber Removal Specification Development: Field Evaluation Procedures Development</u>, DOT/FAA/PM-84/27, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC, 1984.

*Other names such as "popcorn mix" or "plant mix seal" are commonly used to refer to PFS surfaces.

integrity of the underlying pavement layers is also important, because subsidence, rutting, and so forth will interfere with drainage characteristics. The open-graded aggregate mixture also has lower shear strength than uniformly graded aggregate mixes. This results in a lower Marshall stability of PFS, which is reflected as compaction under continued traffic. If compaction becomes excessive the result is rutting or raveling of the PFS. In Figure 1 (Ref. 2), the total voids are plotted versus voids filled with asphalt for samples of PFS from several existing runways. The results for Hill Air Force Base and Denver's Stapleton Airport are of particular interest because rubber removal has been reported by both. They are both below the generally accepted minimum voids recommended in Reference 3. These mixes also exhibit a strong tendency toward reduced voids under traffic. The majority of the other PFS materials shown in Figure 1 are from runways in Europe and Great Britain; they obviously exhibit different mix characteristics.

Table 1 presents the specifications currently found in the Federal Aviation Administration's Advisory Circular on Skid Resistant Pavements (Ref. 4). The specification for interim Item P-402 Porous Friction Course (Central Plant Hot Mix) requires aggregates which are abrasion-resistant, sound, have greater than 75-percent fractured faces, are nonstripping, and have an open gradation. The asphalt cement specification is typical for paving asphalts. The major differences in the specifications and normal mixtures are the aggregate gradation and quality. In addition the underlying pavement must have good drainage and be structurally sound.

An important maintenance problem encountered with PFS runways is damage resulting from accidental fuel spills. The asphalt binder dissolves rapidly when exposed to aircraft fuel. The problem is worse on a PFS surface because of the open-graded mixture. The fuel can move into the voids in the same manner as water, resulting in a greater amount of asphalt binder being dissolved. Accidents resulting in significant damage to runway surfaces at United States Air Force installations prompted the study of fuel-resistant surfaces. Materials studied for the purpose of developing fuel-resistant PFS included tar-rubber and emulsified tar (Ref. 2). Subsequent studies have provided a recommended mix design for fuel-resistant PFS. These materials are scheduled for field evaluation of performance under traffic in the near future. The use of a new family of binders may impact rubber removal operations and should be considered at the time they are introduced.

PFS surfaces are employed in different ways. Most U.S. Air Force installations have Portland cement concrete (PCC) runway ends with PFS surfaces placed in the interior portion of the runway. In this case the touchdown area

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2. Clark, James I., and Watson, James E., Special Study: Maintenance of Porous Friction Surfaces, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, June 1980.

3. White, Thomas D., "Field Performance of Porous Friction Surface Course," Miscellaneous Paper S-76-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, April 1976.

4. Methods for the Design, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces, AC 150/5320-12, Federal Aviation Administration, June 30, 1975.

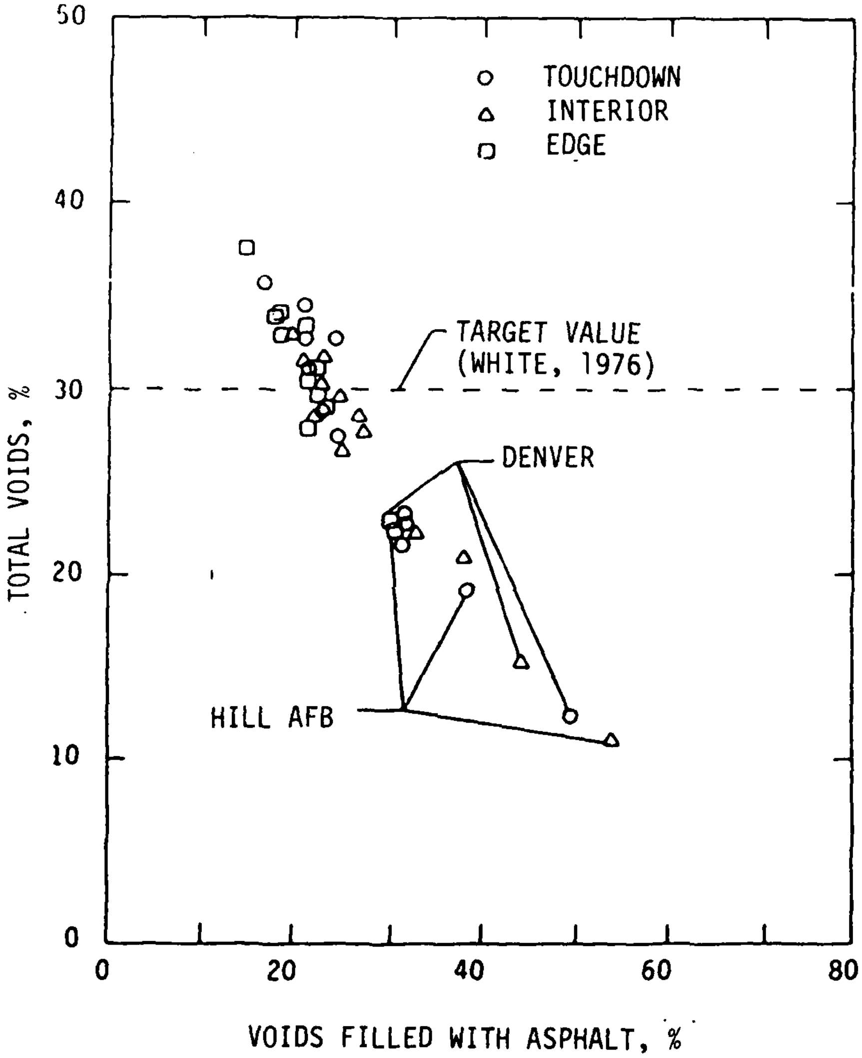

FIGURE 1. MIXTURE CHARACTERISTICS OF EXISTING PFS (REF. 2)

TABLE 1. INTERIM ITEM P-402 POROUS FRICTION COURSE (REF. 4)

Component	Property	Test Method	Requirement
Aggregate > No. 4	Resistance to abrasion	[a]ASTM C131	< 25%
Aggregate > 3/8 in	Flat or elongated pieces	ASTM D693	< 15%
Aggregate < 3/4 in > No. 4	Soundness--sodium sulfate	ASTM C88	< 9%
Aggregate < 3/4 in > No. 4	Soundness--magnesium sulfate		< 12%
Aggregate < 3/4 in > 1/4 in	Coating and stripping of bitumen-aggregate mixtures	ASTM 1664	> 95%
Aggregate > No. 8	Fractured faces (two or more)		> 75%
< No. 8 > No. 30	Fractured faces (two or more)		> 90%
Mineral filler		ASTM D242	
Binder	Bituminous material	[b]AASHTO M20 or AASHTO M226	5 - 7%

[a]American Society for Testing and Materials.
[b]American Association of State Highway and Transportation Officials.

is largely on the PCC surface. The center portion of the runway is where braking occurs, taking advantage of the PFS surface characteristics to ensure high tire-pavement friction. In contrast, many civilian airports place PFS surfaces over the entire length of the runway. In such cases rubber is deposited on the PFS.

As stated above, PFS allows water into the void space, preventing development of a water layer necessary for tire hydroplaning. Rubber deposited on PFS may interfere with this in two ways. Firstly, loose rubber debris may enter the void space, preventing water drainage. Secondly, the surface may become coated with rubber, preventing water from entering the void space. Therefore rubber removal from PFS may be required to restore its desirable friction characteristics. In this regard several questions need to be addressed:

1. Can rubber be removed from PFS?

2. Will removal operations damage the PFS?

3. What method is "best" for accomplishing rubber removal from PFS?

FRICTION MEASUREMENTS

The current standard measure of runway friction used by the Federal Aviation Administration (FAA) and the United States Air Force (USAF) is the Mu Meter. In addition the USAF has used the diagonally braked vehicle. Table 2 shows comparisons of mean Mu values for 28 different pavement surface types studied in the National Runway Friction Measurement Program (Ref. 5). Data shown are mean values of Mu for many tests in areas with and without rubber buildup. In this report, rubber buildup was rated in terms of the percent of the surface covered with rubber. Data in Table 2 shown as rubber had a rating of greater than 30 percent. These data clearly show that a PFS offers an alternative whose performance is competitive with grooved pavements, in terms of the Mu Meter friction coefficient. Other studies by the FAA also indicate that grooving and PFS are quite comparable in terms of developed friction coefficient (Ref. 6). Since PFS is often less costly to construct than grooving, it is a viable alternative. It should be pointed out, however, that aircraft and Mu Meter operational characteristics may not be the same. While Mu values are considered to be the current standard, their relation to aircraft performance is not precisely defined.

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5. MacLennan, J. R., Wench, N. C., Josephson, P. D., and Erdmann, J. B., National Runway Friction Measurement Program, FAA-AAS-80-1, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC, 1980.

6. Agrawal, S. K., and Daiutolo, H., "Effects of Groove Spacing on Braking Performance of an Aircraft Tire," Transportation Research Record 836, Transportation Research Board, Washington, DC, 1981.

TABLE 2. RANKING OF PAVEMENT TYPES BY MEAN WET MU VALUE

PAVEMENT TYPE	TEXTURE† DEPTH in x 10^{-3}	WET MU VALUE (50 60 70 80)
Asphalt, Porous Friction Course	48.5	R 0
Asphalt, Chip Seal*	24.7	0
Asphalt, Microtexture, Grooved	12.7	R 0
Asphalt, Worn	35.0	R 0
Asphalt, Macrotexture	27.7	R 0
Concrete, Wire Tined, Grooved*	20.9	0
Concrete, Burlap Dragged, Grooved	11.9	R 0
Asphalt, Mixed Texture, Grooved	15.9	R 0
Asphalt, Macrotexture, Grooved	23.3	R 0
Asphalt, New, Grooved	15.3	R 0
Asphalt, Rubberized Chip Seal*	39.9	0
Concrete, Worn, Grooved*	12.8	0
Asphalt, Worn, Grooved*	24.7	0
Concrete, Microtexture, Grooved	11.0	R 0
Asphalt, Slurry Seal*	19.0	0
Concrete, Macrotexture, Grooved*	12.0	0
Concrete, Broomed or Brushed, Grooved	10.5	R 0
Concrete, Wire Tined	22.2	R 0
Concrete, Wire Combed	18.0	R 0
Asphalt, Mixed Texture	19.3	R 0
Concrete, Macrotexture*	16.5	0
Asphalt, Microtexture	14.2	R 0
Concrete, Float Grooved	12.5	R 0
Concrete, Worn*	12.8	0
Concrete, Broomed or Brushed	14.5	R 0
Asphalt, New	12.5	R 0
Concrete, Microtexture	12.4	R 0
Concrete, Burlap Dragged	13.9	R 0

0 - Mean value with no rubber
R - Mean value in rubber areas (30 percent rubber accumulation)
* - Insufficient data to analyze in rubber area
† - Texture depth by NASA grease smear test (Ref. 7) in non-rubber areas, the influence or grooving not included for grooved pavements

Note that even when covered with rubber deposits the PFS data indicate a high mean Mu value for the pavements measured. These data indicate that choking of the PFS due to rubber buildup apparently was not a problem at civilian airports during the period of the National Runway Friction Measurement Program (1978 to 1980).

Also shown in Table 2 is texture depth, as measured with the NASA Grease Smear Test (Ref. 7). This is considered to be a measure of the pavement surface macrotexture which is related to friction. It is generally recognized that a minimum level of macrotexture is necessary to maintain satisfactory surface friction characteristics. In addition, the surface microtexture is recognized as a separate pavement surface parameter contributing to surface friction.

RUBBER REMOVAL

Rubber deposits on runways are generally removed by high-pressure water. The choice is primarily one of cost, high-pressure water being the cheapest method for rubber removal. The following discussion presents a brief review of existing methods.

High-pressure water blasting involves spraying water from a spray bar at pressures up to about 8000 lb/in^2. Variables of importance in determining performance are the water pressure, distance from the surface, forward speed, orifice size, spray angle, and flow rate (Ref. 8). Currently no rational procedure exists for determining the values of these parameters for use because pavement conditions vary. The actual settings are determined by trial and error. No procedure exists to determine the amount of rubber removed or the improvement in surface characteristics that result from removal. Current practice involves a subjective evaluation of the quality of rubber removal by airport maintenance personnel. Once a satisfactory test strip is cleaned, the high-pressure water equipment is usually operated at similar settings throughout the area being cleaned. One airport contacted uses the NASA Grease Smear Test as a criterion for acceptance of the rubber removal contractors performance.* Damage to pavements caused by high-pressure water blast may occur if the equipment stops or moves too slowly, or if the pavement surface is in poor condition. Sound pavements are not damaged by high-pressure water when the equipment is used properly.

Rubber may also be removed from runways by using chemicals. This technique is used at several airports in the United States (Los Angeles, New York, Houston, Washington National, Detroit, Reno). These are generally busy airports that must remove rubber frequently. Several commercial products are

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7. Leland, T.J.W., Yager, T. J., and Joyner, U. T., Effects of Pavement Texture on Wet-Runway Braking Performance, NASA TN D-4323, National Aeronautics and Space Administration, Hampton, Virginia, 1968.

8. Carpenter, Samuel H., and Barenberg, Ernest J., Rubber Removal From Porous Friction Course, DOT/FAA/PM-83/31, Federal Aviation Administra tion, Washington, DC, 1983.

*O'Brien, Len, Miami International Airport Aviation Department, Contract Maintenance, personal correspondence, 1983.

available and manufacturers claim that all environmental regulations are met. The use of chemicals is limited to Portland cement concrete (PCC) runways. Experimental evaluation on asphalt-concrete surfaces have been made. Problems are usually encountered in controlling the reaction so that optimum rubber softening occurs without damaging the pavement binder.

Procedures for use of chemicals involve spraying the chemical on the surface and allowing a reaction time followed by washing the chemical and rubber debris off the runway with water. On PCC runways the reaction time is not a critical factor since the chemicals used do not react with PCC. A judgment is made to evaluate the degree of reaction based on experience.

The current development of fuel-resistant PFS indicates that chemical methods may have potential for removing rubber from these surfaces. A study of compatibility between the surface and solvent would be required. Complete sealing of any underlying layers containing asphalt binders would also be required to prevent damage to underlying layers.

Several methods of removing rubber by blasting the surfa[illegible] [illegible]th shot or sand have been reported. These are not generally used. Rea[illegible] are primarily the cost as compared to water blasting and chemicals. Additional problems are caused by foreign object damage (FOD) due to debris that remain [illegible] the runway. In cases that involve other operations on the pavement, such as milling or texturing the surface, in addition to rubber removal, shot blasting becomes a competitive alternative.

One report of rubber removal using a steel-tipped brush was found in this study (Ref. 8). Details are very sketchy, but indicate good results. No source of the equipment or services was found in this review.

Numerous persons contacted have provided evidence that rubber buildup and removal are strongly influenced by environmental factors such as temperature and precipitation. Airport maintenance operations like snow removal and washing of pavements both are reported to reduce the amount of rubber on pavement surfaces.

EXISTING POROUS FRICTION SURFACES

A comprehensive survey of existing runway surfaces was conducted in the National Runway Friction Measurement Program (NRFMP). Results of the study indicate 2939 test sections having porous friction surfaces were evaluated. These represented 51 runways within the continental United States; all are involved in commercial air carrier operations. These data seem at variance with reports of recent studies intended to evaluate PFS experience (Refs. 2 and 8). In these reports only a handful of sites were identified--eight civilian airports and four military airfields in the continental United States.

Rubber rating data in the NRFMP report (Ref. 5) indicate 38 test sections had significant rubber buildup which reduced the mean Mu value from 77.5 to 67.5. This reduction yields a friction coefficient well above the accepted minimum. The results indicated only 3 PFS test sections of the 2939 tested had Mu values below the generally accepted minimum of 50. This clearly indicates that PFS retains acceptable friction characteristics according to these

data. It is not clear from the report whether this retained friction is due to a high retained friction level when covered with rubber or a lack of rubber buildup on the PFS.

DISCUSSION

Two questions were listed in the Introduction as requiring answers in the course of this investigation:

1. Is it possible to remove rubber deposits from a PFS?

2. What are the best alternatives for doing so?

As a result of this study a third question is addressed first:

3. Is it necessary to remove rubber from PFS?

Beginning with the last question, the following discussion addresses these problems. The use of PFS differs between military and civilian runways. The U.S. Air Force employs PFS in the center portion of runways, where braking is normally accomplished. Runway ends, usually about 305 m (1000 feet) are made of portland cement concrete (PCC). The PCC serves better under the static wheel loads of stationary aircraft as well as fluid leaks which frequently occur where aircraft stand. As a result most of the touchdown area and therefore rubber deposits are on the PCC portion of the pavement. It can be concluded that PFS located in the interior part of runways usually do not require rubber removal because they are not in the touchdown area of the runway.

Many civilian airports use PFS on the entire length of the runway. It has been utilized as a cheaper alternative than pavement grooving to achieve good drainage and pavement surface friction characteristics. In this configuration the PFS is subjected to aircraft touchdown and the accompanying tire abrasion associated with wheel spin-up. However, a wide range of field experience has been reported for this specific scenario. Three cases are outlined for discussion.

Case I is a small air carrier facility in a hot-wet climate. Rubber removal has always been a normal maintenance activity and was continued when the PFS was installed. Over a period of 10 years the experience indicates no particular problem with rubber buildup or its removal, when accomplished at regular intervals (in this case about 1 year). Factors to consider are 1) light to moderate air carrier equipment and volume, 2) hot-wet climate, and 3) regular cleaning with high pressure water.

Case II is a larger air carrier airport in a cold-dry climate and rubber removal has not been performed. The PFS has been installed for about 10 years and continues to perform satisfactorily. No rubber removal has been performed since it was constructed. Inspection of the PFS indicates there may be significant rubber deposits; however, this is a subjective visual determination. No operational problems have occurred and therefore no rubber removal has been performed. Over a period of 10 years satisfactory performance has been obtained without rubber removal. Factors to consider are 1) moderate air carrier equipment and volume, and 2) cold-dry climate (low rainfall, snow removal).

Case III is a large air carrier airport with a high traffic volume located in a cold-dry climate. Rubber removal is a routine maintenance activity. After several years concern about rubber deposits led to removal operations using high pressure water. The PFS was in poor condition due to the failure to construct the material in accordance with accepted specifications. Since this particular runway was surfaced in an early period (for PFS), it is not clear whether proper specifications were used or not. It is clear the existing pavement was accumulating rubber, had very low voids (for a PFS), did not adhere well to the underlying pavement, exhibited some raveling, and suffered isolated damage due to fuel or oil leaks dissolving the binder. The application of high pressure water to the surface resulted in serious damage to the PFS. The question was raised as to whether rubber could be removed from PFS satisfactorily and without damage.

The three cases described above are representative of the experience with PFS in the continental United States. The specific cases are made up from the many conversations with airport maintenance personnel and rubber removal contractors during this investigation. The questions of interest are, first, "Is it necessary to remove rubber from PFS?" In a wet climate or with high traffic volume it is necessary to remove rubber from PFS for it to function properly. Certainly those pavements with PFS in the interior and PCC ends do not require rubber removal from the PFS. Others, it appears, do require rubber removal. The lack of rubber removal cited in Case II is believed to be satisfactory only because of a dry climate and the rubber removed during snow removal operations. It is questionable whether normal rubber removal can be accomplished on deposits that have been on the pavement for extended periods of time. Long term physical and/or chemical interactions between the rubber, paving materials, and climate are believed to enhance the adhesion, making removal extremely difficult. It is concluded the PFS cited in Case II cannot function fully due to the rubber deposits present. Because of the climate it is located in, that is not a controlling factor.

The second question, "Is it possible to remove rubber deposits from PFS?" Experience indicates, yes. However, there are some specific limitations that should be considered. Rubber deposits should be removed regularly. Otherwise long term increases in adhesion will make it more difficult to satisfactorily remove rubber. The PFS must be properly constructed and in good condition. Poor quality or damaged PFS structures are very susceptable to damage from high pressure water used in rubber removal.

Finally, question three, "What is the best alternative for rubber removal from PFS?" The only method that has been used is high pressure water. No other available method was found in this investigation that offers a significant advantage. Some techniques may be worth investigating to determine feasibility; however, these are clearly research experiments and do not at this time offer commercially viable alternatives.

It would be beneficial to demonstrate conclusively the feasibility of removing rubber from PFS pavements. This could be accomplished through experiments or practical experience on real pavements. The use of laboratory tests involves the comprising of many factors that may be important in a field situation. These include construction practices, material variability, aging, environment, and so on.

Field experiments may be conducted as designed experiments or as surveys of actual operations. The number of PFS runways and the frequency of removal operations indicate potential for developing an excellent experience base by observing actual operations. Careful documentation of details will provide ample data for use in evaluating the possibility of rubber removal from PFS pavements.

CONCLUSIONS

1. PFS runways subjected to moderate aircraft traffic accumulate rubber deposits.

   a. This may not be a significant problem in dry climates.

2. Rubber deposits may be satisfactorily (subjective judgment) removed from PFS runways.

   a. Assuming the PFS is properly constructed in accordance with current specifications.

   b. Assuming the PFS is not damaged prior to rubber removal.

   c. When regular removal operations are conducted.

3. The only method known to satisfactorily remove rubber deposits from PFS is the high-pressure water method.

RECOMMENDATIONS

1. An objective means of assessing the buildup of rubber and the acceptability of its removal is needed (currently the subject of a study by NMERI, see Ref. 1).

2. Controlled field experiments are needed to assess the parameters involved in rubber removal from PFS. The available experience is confounded by many important factors either not determined or out of control.

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